Out-patient antimicrobial drug use in dogs and cats for new disease events from community companion animal practices in Ontario

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Abstract — This study investigated oral and parenteral antimicrobial use in dogs and cats, and evaluated antimicrobial use in feline upper respiratory tract disease (FURTD), feline lower urinary tract disease (FLUTD), and canine infectious tracheobronchitis. Study journals (n = 1807) were submitted by 84 veterinarians. Sixty-five percent of the antimicrobials prescribed in dogs and 67% in cats were β-lactams. Most frequently prescribed in dogs were cephalexin (33%) and amoxicillin-clavulanic acid (16%), and in cats, amoxicillin-clavulanic acid (40%) and cefovecin (17%); 7% of the prescriptions in dogs and 12% in cats were for fluoroquinolones. Sixty-seven percent of the disease events associated with canine infectious tracheobronchitis, and 70% and 74% associated with FURTD and FLUTD, respectively, were treated with antimicrobials. These results suggest that cefovecin and fluoroquinolones may be over-used and antimicrobial use for the treatment of FURTD, FLUTD, and canine infectious tracheobronchitis could probably be reduced to lessen resistance selection pressure without compromising patient health.

Résumé — **Utilisation des médicaments antimicrobiens chez les chiens et les chats en consultation externe pour les nouvelles instances de maladie dans des pratiques communautaires pour animaux de compagnie de l'Ontario.** Cette étude a examiné l'usage des antimicrobiens oraux et parentéraux chez les chiens et les chats et a évalué l'utilisation des antimicrobiens pour les maladies félines des voies respiratoires supérieures (MFVRS), les maladies félines des voies urinaires inférieures (MFVUI) et la trachéobronchite infectieuse canine. Des journaux d'étude (n = 1807) ont été soumis par 84 vétérinaires. Soixante-cinq pour cent des antimicrobiens prescrits chez les chiens et 67 % de ceux prescrits chez les chats étaient de la classe des β-lactames. Les plus fréquemment prescrits chez les chiens étaient la céfalexine (33 %) et l'amoxicilline avec l'acide clavulanique (16 %), et, chez les chats, l'amoxicilline avec l'acide clavunalique (40 %) et la céfovécine (17 %); 7 % des prescriptions chez les chiens et 12 % de celles chez les chats étaient pour les fluoroquinolones. Soixante-sept pour cent des instances de maladies associées à la trachéobronchite infectieuse canine et 70 % et 74 % de celles associées aux MFVRS et aux MFVUI, respectivement, ont été traitées avec des antimicrobiens. Ces résultats suggèrent que la céfovécine et les fluoroquinolones peuvent être surutilisées et que l'utilisation des antimicrobiens pour le traitement des MFVRS, des MFVUI et de la trachéobronchite infectieuse canine pourrait probablement être réduite afin d'atténuer la pression liée au choix en rapport avec la résistance sans compromettre la santé des patients.

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Introduction

The discovery of antimicrobials for the treatment or prevention of bacterial infections is among the most important advances in modern medicine. However, shortly after their discovery, acquired antimicrobial resistance was observed to adversely affect clinical outcomes (1). Antimicrobial use in humans and animals is an important contributor to antimicrobial resistance, yet few published data are available regarding antimicrobial use in companion animal veterinary practice. Previous studies generally reported frequencies (2,3) or quantities of antimicrobial use (4). The few studies that investigated appropriate antimicrobial selection were performed in study

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populations from teaching veterinary hospitals (2,6,7) that may not be representative of community veterinary practices, or were based on surveys which are subject to recall bias (5).

Documenting how, why, and which antimicrobial drugs are used in general veterinary practice, and the circumstances of their use, is necessary to determine whether improvements are needed. Therefore, the objectives of this study were to 1) describe non-topical antimicrobial use in dogs and cats in Ontario, Canada, and 2) to evaluate antimicrobial use in feline upper respiratory tract disease, feline lower urinary tract disease and canine infectious tracheobronchitis.

Materials and methods

Veterinarian recruitment

Letters describing the study were mailed to general practice companion animal veterinarians located in Ontario that were identified using the College of Veterinarians professional classification codes (8). Veterinarians certified by the American Board of Veterinary Practitioners (canine or feline) were included. All other specialities were excluded from recruitment. Veterinarians were asked to respond to the initial recruitment letter whether they were interested (or not) in the project; those who responded with interest were contacted by telephone to discuss the project prior to committing to participation.

Data-entry journal pre-test

Ten randomly selected respondents agreed to pre-test a study journal using instructions provided for case eligibility. They completed a feedback questionnaire addressing the inclusion and exclusion criteria, difficulties in understanding or completing the journal, time required to complete the journal, and the number of potential eligible patients presented to their practice on the day that they completed the journal. Additionally, the pre-test veterinarians were contacted by telephone to discuss their experience with the study or journal. The completed pre-test journals were evaluated for completeness and clarity of the data provided, which were then entered into the study database to assess its suitability. Following the pre-test, the journal was modified and the definition of case eligibility was refined. The pre-test data were excluded from the study.

Eligibility criteria

Eligible dogs and cats were those diagnosed with incident disease events. These animals were presented through front office, house call, or after-hours/emergency appointments and were managed as outpatients. Information was collected on incident disease events that were treated with prescription or non-prescription medications, in which treatment was deferred pending the results of diagnostic testing, or in which treatment was not required or declined by the client. Additionally, in order to enhance the accuracy of disease frequency estimates (as reported by veterinarians), data were collected on incident disease events that would normally have been managed on an out-patient basis, but the animal had been euthanized for one or more reasons.

An incident disease event was defined as any new abnormality consistent with a disease or pathological process worthy of notation in the medical record, whether or not it required treatment at the time of presentation. This definition included disease events that recurred after a period of resolution (skin infections, for example, as assessed by the attending veterinarian), or other disease events, such as weight changes or dental disease.

Sample size estimation

Data from the pre-test determined that the median number of eligible patients on a given day was 3 (range: 1 to 10). Previous experience in community-based research in a similar veterinary population suggested that the positive response rate of veterinarians to the recruitment letter would range from 6% to 24%. We estimated that up to 5 eligible patients per veterinarian per journal day would provide us with data from 2000 to 6000 patients (with 100% compliance). Previous experience suggested that compliance by the participating veterinarians would range from 30% to 50%, providing data from 1000 to 3000 patients.

Data collection

Veterinarians were asked to participate for a 12-month period and were assigned one of 4 days in a month (Day 3, 11, 19, or 27), through a formal randomization process, to complete their journal for up to a maximum of 5 eligible patients that were presented on each of their journal days. The information gathered in the journal included signalment of the animal, name(s) of incident disease event(s), duration (acute, chronic or recurrent), severity (mild, moderate, severe), pre-existing disease conditions, diagnostic tests performed (such as, history, physical examination, biochemistry, bacterial culture, and antimicrobial susceptibility), type of patient contact (for example, scheduled office appointment, emergency), and treatment administered or prescribed (for example, no treatment, treatment with prescription medications, owner declined therapy). Veterinarians were given the choice to complete the journal in a hard (paper) copy or identical electronic format. Veterinarians indicated on a form when no eligible cases were available for a particular month. Veterinarians who were not working on their assigned day in a particular month were instructed to complete the journals on their next working day.

Statistical analysis

General descriptive statistics

All data were entered into a project specific database (Created in Microsoft Access 2003; Microsoft Corporation, Redmond, Washington, USA) and data analysis was performed using commercial software (Intercooled STATA 10; StataCorp, College Station Texas, USA; Microsoft Excel; Microsoft Corporation). Descriptive statistics were performed by describing categorical variables as proportions and continuous data as medians with ranges. The analysis was limited to disease events that were treated with non-topical antimicrobials (administered orally or parenterally). Frequencies of use of antimicrobials were described according to the first-line, second-line, or third-line classification of therapy as described by Weese (2), and to the Category I, II, or III classification for importance to human health, as defined by the Government of Canada (9).

The disease event descriptions were classified by specific body sites or disease conditions (Tables 1 and 2). The frequency of

Table 1. Frequencies of non-topical antimicrobial prescription events for incident disease events[a] in dogs reported by veterinarians

Antimicrobial	Overall (N = 486) *n* (%)	Skin (N = 153) *n* (%)	GI (N = 90) *n* (%)	Urinary (N = 32) *n* (%)	Respiratory (N = 28) *n* (%)	Anal gland (N = 22) *n* (%)	Dental/Oral (N = 23) *n* (%)	Ears (N = 14) *n* (%)	Digits, eyes, genitalia (N = 21) *n* (%)
β-lactams									
Amoxicillin	44 (9)	6 (4)		8 (25)	2 (7)	1 (5)	3 (14)	1 (7)	6 (29)
Amoxicillin-clavulanic acid	78 (16)	21 (14)		12 (38)	5 (18)	12 (55)	6 (26)	1 (7)	2 (10)
Ampicillin	5 (1)	1 (0.6)	1 (1)		2 (7)				1 (5)
Cefazolin	1 (0.2)								
Ceftiofur	3 (0.6)	2 (1)							
Cefovecin	19 (4)	9 (6)	1 (1)	2 (6)	1 (4)		1 (4)	1 (7)	
Cephalexin	160 (33)	103 (67)		4 (13)	2 (7)	4 (18)	2 (9)	7 (50)	9 (40)
Procaine penicillin[b]	6 (1.2)		2(2)		1(4)				1 (5)
Fluoroquinolones									
Enrofloxacin	24 (5)	6 (3)		6 (19)	1 (4)	1 (5)		2 (14)	1 (5)
Marbofloxacin	5 (1)	1 (0.6)	1 (1)		2 (7)				
Orbifloxacin	5 (1)	1 (0.6)			1 (4)	1 (5)		1 (7)	
Lincosamides									
Clindamycin	15 (3)	1 (0.6)					11 (48)		1 (11)
Macrolides									
Azithromycin	3 (0.6)	1 (0.6)			1 (4)				
Erythromycin	1 (0.2)		1 (1)						
Tylosin	15 (3)		12 (13)						
Tetracyclines									
Doxycycline	4 (0.8)				3 (11)				
Tetracycline	1 (0.2)								
Tetracycline, novobiocin, and prednisolone	4 (0.8)				2 (7)				
Sulfonamides									
Sulfadimethoxine	5 (1)	1 (0.6)	4 (4)			2 (7)			
Trimethoprim/ Sulfadiazine	5 (1)		4 (4)						
Other									
Chloramphenicol	5 (1)				4 (14)				
Metronidazole	78 (16)		64 (71)		1 (4)	1 (5)			

Blank spaces = 0.
[a] Veterinarians' disease event descriptions were aggregated into body sites or specific disease conditions. Antimicrobial prescriptions for body sites, specific disease conditions, or clinical signs where $n < 5$ are described in Murphy (19).
[b] Includes procaine benzathine penicillin.
GI — gastrointestinal; N — total number; *n* — number.

antimicrobial treatments in specific body sites or disease conditions was calculated by the following formula:

$$\frac{\text{Number of prescription events with non-topical antimicrobial “X” in body site “Y”}}{\text{Total number of non-topical antimicrobial prescription events in body site “Y”}}$$

Associations between the length of oral antimicrobial therapy and severity (mild versus moderate or severe) or duration (acute versus chronic or recurrent) of disease were determined using the Mann-Whitney U-test with significance at $P \leq 0.05$. Associations among the severity or duration of the disease event, animal species and use of bacterial culture and antimicrobial susceptibility testing were determined using Fisher's exact test with significance at $P \leq 0.05$ where the 95% confidence interval (95% CI) did not include the null.

Non-topical antimicrobial use in specific diseases

Non-topical antimicrobial use was described for feline upper respiratory tract disease, feline lower urinary tract disease, and canine infectious tracheobronchitis (Table 3). In addition, associations between non-topical antimicrobial treatment and severity of disease (mild versus moderate/severe), duration of the disease (acute versus chronic/recurrent), and gender were determined using the Fisher's exact test with significance at $P \leq 0.05$ where the 95% CI did not include the null. Associations between non-topical antimicrobial treatment and age or weight were determined using the Mann Whitney U-test with significance at $P \leq 0.05$.

Results

Demographics

Recruitment letters were mailed to 2406 veterinarians in Ontario and 218 responded (overall response rate: 9%), with 178 expressing interest in participating in the study (positive response rate of respondents: 82%). Positive respondents were contacted by telephone to further discuss the project and 109 agreed to participate. Eighty-two percent of the study-participants were graduates from the Ontario Veterinary College and the median year of graduation was 1991 (range: 1956–2006). Female veterinarians were overrepresented ($P < 0.01$) in the study population (67%) when compared

ARTICLE

Table 2. Frequencies of non-topical antimicrobial prescription events for incident disease events[a] in cats reported by veterinarians in the submitted journals

Antimicrobial	Overall (N= 219) *n* (%)	Respiratory (N = 35) *n* (%)	Urinary (N = 29) *n* (%)	GI (N =24) *n* (%)	Abscess (N = 18) *n* (%)	Skin (N = 18) *n* (%)	Dental/Oral (N= 13) *n* (%)	Bite (N = 12) *n* (%)	Digits, wound, ear, anal gland (N = 17) *n* (%)
β-lactams									
Amoxicillin	11 (5)	3 (9)	2 (7)			1 (6)			2 (12)
Amoxicillin-clavulanic acid	88 (40)	13 (37)	16 (55)	3 (12)	9 (50)	12 (67)	4 (31)	6 (50)	6 (35)
Ampicillin	4 (2)			2 (8)			1 (8)		
Cefovecin	38 (17)	4 (11)	3 (10)	1 (4)	4 (22)	4 (22)	2 (15)	4 (33)	6 (35)
Procaine penicillin[b]	5 (2.5)			1 (4)	1 (6)				
Fluoroquinolones									
Enrofloxacin	15 (7)	5 (14)	5 (17)						1 (6)
Marbofloxacin	4 (2)		2 (7)		1 (6)			1 (8)	
Orbifloxacin	7 (3)	2 (6)	1 (3)	1 (4)		1 (6)			1 (6)
Lincosamides									
Clindamycin	16 (7)				3 (17)		6 (46)	1 (8)	1 (6)
Macrolides									
Azithromycin	4 (2)	3 (9)							
Erythromycin	2 (1)	1 (3)		1 (4)					
Tylosin	2 (1)								
Tetracyclines									
Doxycycline	4 (2)	4 (11)							
Tetracycline	1 (0.5)			1 (4)					
Tetracycline, novobiocin and prednisolone	1 (0.5)								
Other									
Metronidazole	18 (8)			12 (50)					

Blank spaces = 0.
[a] Veterinarians' disease event descriptions were aggregated into body sites or specific disease conditions. Antimicrobial prescriptions for other body sites, specific disease conditions or clinical signs are described in Murphy (19).
[b] Includes procaine benzathine penicillin.
GI — gastrointestinal; N — total number; *n* — number.

to the proportion of female companion animal veterinarians in Ontario (54%). Ninety-three percent of the participants described themselves as companion animal veterinarians and 7% as mixed animal veterinarians.

Over the study period, 1807 journals were submitted by 84 veterinarians (total number enrolled n = 109; participation rate: 77%). The median number of months of participation was 9 (range: 0–13). Twelve veterinarians formally withdrew from the study over the study period (no reason reported n = 9, parenteral leave n = 2, changed type of practice n = 1).

Journals

Of the 1807 journals submitted, 70% (n = 1256) involved dogs. Mixed-breeds were most frequently reported (25%), followed by Labrador retriever (10%), golden retriever (7%), and shih tzu (6%); other breeds were each represented at a frequency of < 3%. Thirty percent (n = 551) of journals involved cats in which 73% were domestic short hair, 13% were domestic long hair, 4% were domestic medium hair, and 3% (n = 14) were Siamese. All other breeds were represented at a frequency of < 2%. The reported medians (range) for age and weight of dogs were 5 y (2 wk to 18 y) and 19 kg (1 to 72 kg); the cat medians were 6 y (1 wk to 22 y) and 5 kg (0.3 to 15 kg). Forty-two percent of the dogs and 35% of the cats were neutered females; 38% of dogs and 51% of cats were neutered males; 8% of dogs

Table 3. The incident disease event descriptions reported by veterinarians that were aggregated for the evaluation of antimicrobial use in feline lower urinary tract disease, feline upper respiratory tract disease, and canine infectious tracheobronchitis

Disease	Disease event descriptions
Feline lower urinary tract disease	Bacterial cystitis, crystalluria, cystitis, hematuria, pollakiuria, urinary tract infection
Feline upper respiratory tract disease	Nasal discharge, rhinitis, sinusitis, tracheitis, upper respiratory congestion, upper respiratory disease, upper respiratory tract infection, upper respiratory tract inflammation
Canine infectious tracheobronchitis	Cough, infectious tracheobronchitis, infectious tracheitis, kennel cough, tracheobronchitis

and 6% of cats were intact females and 12% of dogs and 8% of cats were intact males.

Antimicrobial prescription events

There were 1984 prescription events recorded; 51% (n = 1009) for antimicrobials, of which 70% (n = 705) were non-topical antimicrobials, 17% (n = 171) were otic, 10% (n = 100) ophthalmic, and 3% (n = 33) were skin preparations. Fifty-five percent and 49% of the prescription events in dogs and cats, respectively, were antimicrobials. The incidence rates of antimicrobial

Table 4. Percentages of prescription events with non-topical antimicrobials for incident disease events in dogs and cats by recommended use as first, second, or third line therapy in veterinary medicine[a] and importance for use to treat human infections[b]

Category	Cats (N = 219) *n* (%)	Dogs (N = 486) *n* (%)
Use in veterinary medicine[a]		
First-line therapy[b]	428 (88)	155 (71)
Second-line therapy[c]	58 (12)	64 (29)
Importance for use to treat human infections[d]		
Classification I (Very High Importance)[e]	220 (45)	171 (78)
Classification II (High Importance)[f]	256 (53)	44 (20)
Classification III (Medium Importance)[g]	10 (2)	4 (2)

[a] Weese (2).
[b] Penicillins (penicillin G, amoxicillin, or ampicillin), potentiated penicillins (amoxicillin-clavulanic acid), first-generation cephalosporins (cefazolin or cephalexin), second-generation cephalosporins (cefoxitin), trimethoprim-sulfonamide, tetracyclines (tetracycline or doxycycline), lincosamides (clindamycin, metronidazole), macrolides (erythromycin or tylosin).
[c] Fluoroquinolones, other cephalosporins.
[d] Government of Canada (9).
[e] Third-generation cephalosporins, fluoroquinolones, nitroimidazoles (metronidazole), penicillin-β-lactamase inhibitor combinations.
[f] First and second-generation cephalosporins (including cephamycins), lincosamides, macrolides, penicillins, trimethoprim/sulfamethoxazole.
[g] Phenicols, sulfonamides, tetracyclines, trimethoprim.
N — total number; *n* — number.

prescription events were 23 events per 100 veterinarian-hours worked, 14 events per 100 patients examined and 52 events per 100 patients diagnosed with a new disease event. There were 111 prescription events in which a corresponding disease event was not recorded and 89% (n = 99) of these were prescription events with non-topical antimicrobials.

The most frequently prescribed antimicrobial class was β-lactams for both dogs and cats, representing 65% and 67% of all non-topical antimicrobial prescription events, respectively (Tables 1 and 2). Cephalosporins [predominantly cephalexin; 33% (n = 180) of antimicrobial prescription events] were the most commonly prescribed antimicrobial in dogs, followed by amoxicillin-clavulanic acid (16%, n = 78 of antimicrobial prescription events) and metronidazole (16%, n = 78 of antimicrobial prescription events). The next most frequently prescribed antimicrobials in dogs were fluoroquinolones (7%, n = 34). In cats, amoxicillin-clavulanic acid (40%, n = 88) and cefovecin (17%, n = 38) were the most commonly prescribed antimicrobials. Fluoroquinolones (12%, n = 12) and lincosamides (clindamycin) (7%, n = 16) were the third and fourth most frequently prescribed antimicrobials. In both dogs and cats, all other antimicrobials were prescribed at frequencies $<$ 3%.

In dogs and cats, β-lactams were used to treat disease events in every body site reported by veterinarians (Tables 1 and 2) and were the predominant antimicrobial class used in all body sites, with the exception of the gastrointestinal tract, where metronidazole was the most commonly used (Tables 1 and 2). When prescribed in dogs, fluoroquinolones were mostly used to treat diseases affecting the urinary tract or ears, but also to treat disease events associated with almost every other body site reported by veterinarians (Table 1). In cats, fluoroquinolones were commonly used to treat disease events associated with the urinary tract and the respiratory tract (Table 2). Clindamycin was mostly used to treat disease events associated with the dentition/oral cavity, abscesses and wounds (including bite wounds) (Table 2).

First-line antimicrobials were most frequently prescribed in both cats (71%, n = 156) and dogs (88%, n = 428). Antimicrobials in category I of importance to human health (9) were the most frequently prescribed in cats; in dogs, prescribed antimicrobials were predominately within categories I and II (Table 4).

In dogs, some or all prescription events with ampicillin, cefazolin, cefovecin, ceftiofur, metronidazole, procaine penicillin, procaine/benzathine penicillin, trimethoprim/sulfadiazine and tylosin were administered parenterally by single injection. Excluding treatments with cefovecin (n = 14; for which single injection has a duration of action of 14 d), 5 of these treatments (ampicillin, n = 1, procaine penicillin, n = 2, procaine/benzathine penicillin, n = 1, tylosin, n = 1) were the only antimicrobial prescribed to the animal. In cats, some or all prescription events with ampicillin, cefovecin, enrofloxacin, procaine penicillin, procaine/benzathine penicillin, and tylosin were administered parenterally, all by a single injection. Excluding treatments with cefovecin (n = 9), 3 of these treatments (procaine/benzathine penicillin, n = 2, tylosin, n = 1) were the only antimicrobial therapy prescribed to the animal.

For antimicrobials that were administered orally, the median (range) length of therapy was 10 d in both dogs and cats (range: 1 to 35 d and 4 to 42 d, respectively). Frequently, therapy was prescribed for 7 d (dogs 23%, cats 33%), 10 d (dogs 24%, cats 33%), or 14 d (dogs 28%, cats 20%). Dogs with disease events classified as chronic or recurrent were treated significantly longer [median duration: 10 d (range: 1 to 28 d)] than dogs with acute disease [median duration: 9 d (range: 2 to 21 d) ($P < 0.01$)]. Cats with disease events classified as moderate or severe were prescribed longer therapy [median duration: 10 d (range: 4 to

ARTICLE

Table 5. The percent of events of feline upper respiratory tract disease, feline lower urinary tract disease, and canine infectious tracheobronchitis that were treated with antimicrobials

	Percent treated with antimicrobials		
Antimicrobial	Feline upper respiratory tract disease (N = 28) *n* (%)	Feline lower urinary tract disease (N = 29) *n* (%)	Canine infectious tracheobronchitis (N = 21) *n* (%)
β-lactams			
Amoxicillin	3 (11)	2 (7)	4 (19)
Amoxicillin-clavulanic acid	9 (32)	16 (55)	4 (19)
Cephalexin			2 (9)
Cefovecin	3 (11)	3 (10)	1 (5)
Fluoroquinolones			
Enrofloxacin	2 (7)	5 (17)	
Marbofloxacin		2 (7)	
Orbifloxacin	2 (7)	1 (3)	1 (5)
Macrolides			
Azithromycin	3 (11)		
Erythromycin	1 (4)		
Tetracyclines			
Doxycycline	5 (18)		2 (9)
Tetracycline, novobiocin, and prednisolone combination			2 (9)
Other			
Chloramphenicol			4 (19)
Metronidazole			1 (5)

N — total number; *n* — number.

28 d)] than those with mild disease [median duration: 7 d (range: 5 to 14 d) ($P = 0.04$)].

There were 5188 diagnostic-test events recorded for 1789 animals, and of these, 0.8% ($n = 40$) were bacterial culture and antimicrobial susceptibility. In dogs and cats, bacterial culture and susceptibility was performed in 3% ($n = 17$) and 8% ($n = 15$), respectively, of the disease events treated with antimicrobials; and, in all cases, antimicrobial treatment was prescribed. In dogs and cats, of the bacterial culture and susceptibility testing performed, 59% ($n = 10$) and 67% ($n = 10$) respectively, were performed for disease events associated with the urinary tract. Disease events that were listed as chronic or recurrent were significantly [OR 2.5, 95% CI (1.1, 5) $P = 0.02$] more likely to have a bacterial culture and susceptibility performed than disease conditions listed as acute, and culture and sensitivity were performed more often in cats [OR 2, 95% CI (1.1, 5) $P = 0.04$] than dogs.

Specific disease conditions

Feline upper respiratory tract disease

Incident disease event descriptions that were consistent with feline upper respiratory tract disease represented 6% ($n = 37$) of all disease event descriptions in cats, and 70% ($n = 28$) were treated with antimicrobials (Table 5). These represented 13% ($n = 28$) of all non-topical antimicrobial prescription events in cats. Amoxicillin-clavulanic acid was the most frequently prescribed antimicrobial to treat this condition (32%, $n = 9$), followed by doxycycline (18%, $n = 5$), and fluoroquinolones (14%, $n = 4$). Cats with moderate to severe feline upper respiratory tract disease were significantly more likely to be treated with antimicrobials [OR = 7, 95% CI (1.1, 48) $P = 0.02$] than cats with mild disease. There was no association between antimicrobial treatment and chronicity (acute versus chronic/recurrent) of disease [OR = 2, 95% CI (0.3, 23), $P = 0.7$], age ($P = 0.7$), weight ($P = 0.9$), or gender [OR 1.4, 95% CI (0.2, 10), $P = 1.00$] of the cat.

Feline lower urinary tract disease

Six percent ($n = 39$) of the incident disease event descriptions in cats were consistent with feline lower urinary tract disease, 74% ($n = 29$) of which were treated with antimicrobials (Table 5). Prescription events associated with this condition represented 13% ($n = 29$) of all non-topical antimicrobial prescription events in cats. Amoxicillin-clavulanic acid was the most frequently prescribed antimicrobial (55%, $n = 16$), followed by fluoroquinolones (27%, $n = 8$). There were no significant associations between antimicrobial treatment and severity of disease [OR = 1.4, 95% CI (0.2, 8), $P = 0.7$], chronicity of disease [OR = 0.4, 95% CI (0.1, 2), $P = 0.25$], weight ($P = 0.18$) or gender [OR = 0.67, 95% CI (0.1, 4), $P = 0.7$].

Canine infectious tracheobronchitis

Incident disease event descriptions by veterinarians that were consistent with canine infectious tracheobronchitis represented 2% ($n = 31$) of all disease event descriptions in dogs and 67% ($n = 21$) were treated with antimicrobials (Table 5) and represented 4% ($n = 21$) of all antimicrobial prescription events in dogs. The most frequently prescribed antimicrobials were amoxicillin, amoxicillin-clavulanic acid, and chloramphenicol (19%, $n = 4$ each). Dogs with moderate or severe disease were more likely to be treated with antimicrobials [OR = 29, 95% CI (2, 1337) $P < 0.01$] than dogs with mild disease. There was also a significant difference ($P = 0.002$) in the ages of the dogs that were treated with antimicrobials. The median age of dogs with infectious tracheobronchitis that were treated with antimicrobials was 6 mo (range: 8 wk to 11 y) and the median age of dogs not treated with antimicrobials was 7 y (range: 8 mo to 14 y). There were no significant associations between antimicrobial treatment and chronicity [OR = 0.9, 95% CI (0.1, 7), $P = 1.00$], weight ($P = 0.2$), or gender [OR = 0, 95% CI (0.0, 1.2), $P = 0.14$].

Discussion

Our findings that antimicrobials were the most commonly prescribed medications, with β-lactams as the most frequently prescribed class, are similar to those of previous studies investigating antimicrobial use in a tertiary-care teaching hospital in southern Ontario (2), and in studies from other countries, including those involving first opinion veterinary practices (10), tertiary care veterinary hospitals (6), questionnaires completed by veterinarians describing antimicrobial use (5,11), prescription data from university pharmacies (7), antimicrobial dispensing data collected from veterinary drug wholesalers (3), and a national monitoring system (4). Study veterinarians prescribed predominately first-line antimicrobials and did not report use of any third-line antimicrobials (such as, carbapenems, vancomycin). However, a high proportion of prescriptions were second-line antimicrobials, especially in cats (29%); comprising mainly cefovecin and fluoroquinolone. Cefovecin is a subcutaneously administered long-acting third-generation cephalosporin, with duration of action of 14 d. This mode of administration is attractive in cats, since oral administration can be difficult or in some cases impossible. Third-generation cephalosporins are classified by Health Canada as of very high importance in human medicine (Category I antimicrobials) as they are essential for the treatment of selected serious bacterial infections of humans with limited or no availability of effective alternative antimicrobials in case of resistance to these agents (9). It has been suggested that third-generation cephalosporins be limited to second-line antimicrobial therapy, when supported by bacterial culture and susceptibility data indicating a lack of appropriate first-line options (2). Bacterial culture and susceptibility testing was, however, not recorded in any of the prescription events involving use of cefovecin in dogs or cats in this study.

It has also been suggested that fluoroquinolones should be limited to second-line therapy (2) and, like cefovecin, fluoroquinolones have been classified as of very high importance in human medicine (Category I antimicrobials) (9). The frequency of antimicrobial prescription events with fluoroquinolones reported in this study (overall 9%) is higher than reported in other studies (2–4,6,7,10). For example, in a veterinary teaching hospital in southern Ontario, fluoroquinolones comprised 5% of overall antimicrobial prescriptions (2). This suggests that fluoroquinolone use by general practice companion animal veterinarians in Ontario could probably be reduced.

We also observed use of antimicrobials for feline upper respiratory tract disease, feline lower urinary tract disease, and canine infectious tracheobronchitis, including treatment with cefovecin and fluoroquinolones. Antimicrobials are not always required for treatment of these conditions, as they may not be associated with a bacterial infection (such as, feline lower urinary tract disease), may be self limiting even when associated with other micro-organisms (for example, *Bordetella bronchiseptica, Chlamydophila felis*) or they can be associated with viruses (for example, feline herpes virus, feline calicivirus, canine parainfluenza virus, canine adenovirus, canine influenza virus) (12,13). Antimicrobial use in specific circumstances of feline upper respiratory tract disease is necessary (such as, secondary bacterial infections, chlamydial infections or bordetellosis in kittens); however, these conditions were not reported by the veterinarians in this study. This suggests that antimicrobials may be over-used in feline upper respiratory tract infection in the study population, particularly since 50% ($n = 7$) of cats diagnosed with a mild upper respiratory tract infection were treated with antimicrobials, including cefovecin and fluoroquinolones. Without estimates of the true frequency of the conditions like chlamydiosis or bordetellosis, it is impossible to quantify the justified use of antimicrobials in feline upper respiratory tract infections. However, it is plausible that antimicrobial use could be reduced considerably in cats if the routine use of antimicrobials was discontinued for uncomplicated feline upper respiratory tract disease and feline lower urinary tract disease.

Many veterinary professional organizations have published prudent or judicious antimicrobial use guidelines (14–18). All advocate use of bacterial culture and susceptibility as tools to support diagnosis and as guides to therapy. However, in this study population the frequency of bacterial culture and susceptibility testing was extremely low (overall 4%). A possible reason for the limited use of this test is that bacterial culture and susceptibility testing increases the cost of treatment. This additional cost may be deemed unnecessary; especially when in many situations, antimicrobial treatment would be started before the results are available. However, there are costs associated with inappropriate or improper therapy that could be mitigated through the use of bacterial culture and susceptibility testing. Bacterial culture and susceptibility testing may reduce the occurrence of treatment failures associated with inappropriate antimicrobial treatment from empiric antimicrobial selection. It may also improve use of second- or third-line antimicrobials or those with higher importance to human medicine by narrowing their use to situations in which no other more prudent alternatives are available. Further, increased use of bacterial culture and susceptibility testing may reduce the overall use of antimicrobials by reducing use in patients without a bacterial infection or repeated treatments in the case of treatment failures from empirical selection.

In some situations, body sites, or disease conditions, however, it is difficult or impossible to obtain an appropriate sample for bacterial culture and susceptibility testing such as feline upper respiratory tract infection or canine infectious tracheobronchitis. Therefore, veterinarians rely on other data to determine if antimicrobials are necessary for treatment: history, physical examination, and other diagnostic tests (some of which may be performed in-house). Some of this information is subjective and therefore the assessment and subsequent treatment of a patient may differ among veterinarians. In human medicine, evidence-based clinical guidelines are helpful in patient assessment and treatment (20). In veterinary medicine, similar evidence-based

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clinical guidelines are not as fully developed. Research and subsequent development of evidence-based practice guidelines for common conditions such as feline upper respiratory tract disease or canine infectious tracheobronchitis is necessary. Development of evidence-based practice guidelines using information easily obtained by veterinarians (for example, history, physical examination, in-house diagnostics) may improve antimicrobial use by veterinarians by targeting use to conditions where it is required and improving selection, dosing, and duration of therapy when antimicrobial treatment is prescribed.

Although this study enabled data to be gathered on over 1000 dogs and cats diagnosed with an incident disease event, there were limitations associated with a poor response rate to the initial recruitment letter and bias associated with volunteer participation. These are common limitations to community companion animal research and are difficult to overcome especially with studies in which significant participation is required of the respondents. Further, the effect of this bias on the results is unknown as no research on this subject has been published in veterinary medicine. These are areas where future research is needed; understanding participation in research by veterinarians, the characteristics of veterinarians, veterinary practices, or pet owners that may influence research in community practices.

Another factor to consider when interpreting the results of this study is that the reported frequencies of feline upper respiratory tract disease, feline lower urinary tract disease, and canine infectious tracheobronchitis may not reflect the true frequency of these diseases in this population, but instead, the frequency of diagnosis by veterinarians. The frequency of diagnosis is the measure of interest as this would influence the treatment decisions by veterinarians, and including antimicrobial use. The study described the overall antimicrobial use by veterinarians, and antimicrobial use in specific disease conditions, and provides a good basis for identifying areas in which use may be improved, a baseline for future antimicrobial use studies, and studies that may investigate the true frequency of certain diseases and treatment of those diseases.

In summary, antimicrobials are critical for the management of bacterial infections and veterinarians accept a responsibility for stewardship of these drugs. The findings in this study population suggest that antimicrobial use could be improved by reducing the frequency of use of third-generation cephalosporins (such as, cefovecin) and fluoroquinolones, and reducing the use of antimicrobials in the treatment of feline upper respiratory tract disease, feline lower urinary tract disease, and canine infectious tracheobronchitis. Additionally, veterinarians could make greater use of bacterial culture and susceptibility to support their diagnoses and therapeutic choices.

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